

NF-100

NASA Facts

An Educational Publication
of the
National Aeronautics and
Space Administration

NF 100/10-80

Voyager to Saturn

From Earth, the planet Saturn appears in the pre-dawn hours of November 12, 1980, as a steady yellowish light in the constellation Virgo, outshining all but the brightest stars in the southeastern sky, its splendid rings visible with even a good pair of binoculars. But on that same day, the first of two Voyager spacecraft sees the great Ringed Planet as no one has seen it before, when it makes a second close approach to a planet on its decade-long flyby tour of the outer Solar System.

The Voyager mission takes advantage of state-of-the-art technology as well as a rare orbital alignment of the distant planets Jupiter, Saturn, Uranus, and Neptune to extend man's sight and his imagination billions of miles to regions where the Sun is only a bright star. Having already returned a wealth of information and pictures of amazing color and clarity from their Jupiter flybys in mid-1979, Voyagers 1 and 2 now prepare for their respective encounters with Saturn in November 1980, and August 1981.



*Saturn as Voyager 1 saw it
on September 17, 1980.*

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The Voyager Spacecraft

Seemingly small for the task assigned them, the identical twin Voyagers weigh just under a ton each. The main functions of the spacecraft are clearly seen in its three-part design, beginning with the wide dish antenna for all-important radio communications to and from Earth. Underneath this dish are Voyager's "brains", the three primary and three backup computers—responsible for overall command, collection of science data, and control of the spacecraft's periodic rolls and turns. Finally, extending out from the body is a lattice-like arm, or "boom", where most of Voyager's sensors—its science instruments—are mounted.

Many of these instruments are sensors relating to different bands of the broad spectrum of electromagnetic energy that serves as a prime source of information for scientists. How a body (or a substance such as a gas) absorbs, reflects, emits, or in any way changes this energy tells much about its physical properties, especially if the energy is seen in very specific wavelengths.

And so, Voyager has four different "eyes"—TV or telemetry cameras, ultraviolet and infrared devices, and a light-analyzing photopolarimeter (no longer active on Voyager 1)—located on a scan platform which turns at almost any angle for precise targeting.

Because we cannot yet go ourselves, Voyager goes for us. Its instruments cover the spectrum and detect charged particles and fields.

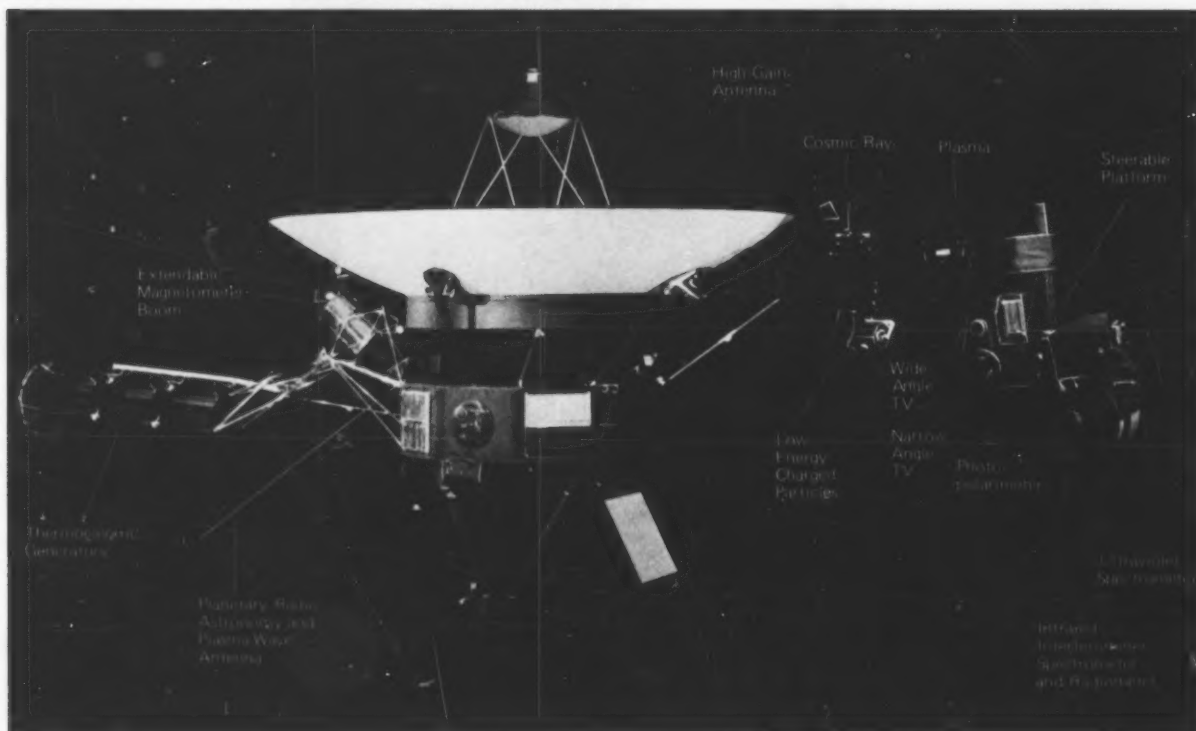
Also on the boom are instruments to see cosmic rays and radio emissions from the planets.

Other science instruments supplement this spectral analysis with a search for highly energetic subatomic particles and fields. These include plasma (charged gas) detectors and magnetometers to survey the magnetic fields around planets.

Certain elements of Voyager's design, including its computer and TV systems, are adapted from the Mariner missions which have already explored the inner planets close to Earth. But in going much farther from the Sun to colder regions of space, Voyager requires special features first used by the Pioneer spacecraft, the first man-made objects to cross the asteroid belt.

Like Pioneer, Voyager is equipped with small nuclear generators to provide onboard electrical power. Earlier missions used solar panels for these energy demands, but Voyager's distance from the Sun makes this impractical, and creates an added need for small heaters and insulation against the cold.

The great distances Voyager will travel also require a giant leap in communications sophistication. Even at its highest output, the dish antenna points a narrow beam of less power than a small light bulb at a target so distant it will take nearly 1½ hours to



reach Earth from Saturn, traveling at the speed of light. The mission depends heavily on a worldwide Deep Space Network of massive ground antennae to pick up and enhance this faint signal and relay it to Voyager Mission Control in Pasadena, Calif. There the computer bits of data are decoded, and the communications link is complete.

From Earth to Jupiter to Saturn

Voyager 1 was launched September 5, 1977, 16 days after the slower, more roundabout Voyager 2. It took one and a half years to travel the 1 billion kilometers (625 million mi.) to Jupiter, the largest planet in our Solar System, whose clouds it passed at a distance of about two planetary diameters on March 5, 1979.

During this encounter with Jupiter, Voyager 1's cameras took many thousands of photos of the giant planet, its atmosphere and Great Red Spot, and four of its brightly colored moons: Io, Europa, Ganymede, and Callisto. These superb pictures and Voyager's other studies led to startling discoveries—a thin ring was found around Jupiter's middle, and the first active volcanoes known to exist beyond Earth were seen on Io's surface.

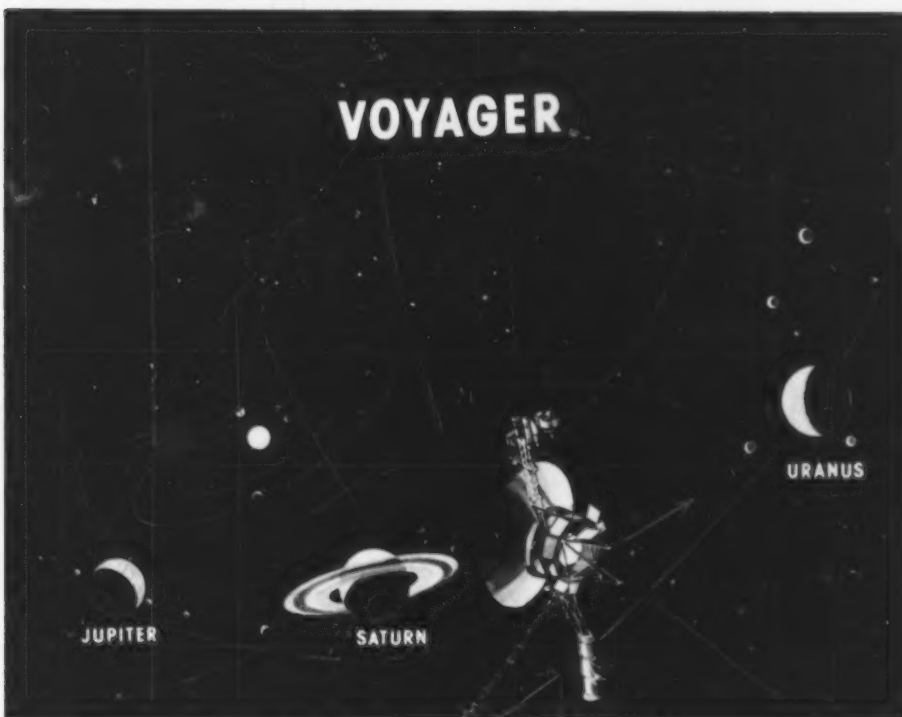
Barely had Voyager 1 finished its backward glances at Jupiter when the second spacecraft

began approach studies prior to its close flyby on July 9, 1979, at twice the distance of the first. An outstanding feature of the Voyager mission is this two-spacecraft design, which allows for complementary trajectory paths and for re-programming of the later craft to investigate such surprises as the Jupiter ring and Io's volcanoes. The second look proved valuable. On closer inspection of the ring's edge Voyager 2 found a small, previously unknown moon (Jupiter's fourteenth), and a fifteenth has since been found.

When it ended a highly successful encounter with the Jupiter system on August 5, 1979, Voyager 2 joined its twin, already bound for Saturn. Voyager 1 takes almost two years to travel the 1.2 billion km (725 million mi.) necessary to intercept Saturn at the proper place in its orbit, even though it crosses the cold, quiet darkness of interplanetary space at speeds faster than any object ever made by man.

The trip would be longer still without the slingshot-like boost Voyager got from Jupiter's powerful gravity during close approach, where changes in speed and direction were further refined by controlled burns of the spacecraft's small thrusters. Several more of these burn maneuvers are undertaken before arrival at Saturn.

This "cruise" phase of the mission is a time of slow, but still important data gathering, combined with a series of many instrument calibrations and



Voyager sends pictures and data back to Earth from Jupiter (1979), Saturn (November, 1980) and Uranus (1986).

navigational tracking tests using the Sun and bright stars. The most important readings during these long months are returned by the fields and particles detectors, as they explore the rich "ecology" of space—the interaction of galactic radiations, emissions from the larger planets, and the steady flow of solar wind radiation streaming from the Sun.

As Voyager gets closer to Saturn in early 1980 and as the rings become brighter due to the Sun's increasing elevation, the returning TV pictures grow in sharpness and detail. By late summer they are better than any available from Earth. Now Voyager's attention turns to an intensive study of the great Ringed Planet, sixth from the Sun, a wonder to dreamers and scientists alike.

The Planet Saturn

Once thought unique because of the marvelous, bright rings around its equator, Saturn is now only one of three known ringed planets, (Jupiter and Uranus are the others). A "gas giant" similar in makeup to Jupiter, it is the second largest body orbiting our Sun. Saturn has the lowest density of any planet, which combines with a very rapid rotation to produce a bulging of about 10% at its equator, much as a spinning water balloon might bulge at the middle.

In contrast to the rocky Earth-like planets, there is no known "surface" on Saturn. We see only its cloudy atmosphere, extending out 60,000 km (37,200 mi.) from the center of the planet, where current data suggests the presence of a very dense, rocky core about the size of the Earth. This is surrounded by gradually less dense layers of liquid hydrogen in a metallic form, compressed water and ammonia ices, and, finally, the hydrogen and helium gases which account for most of Saturn's mass.



Since the planet radiates more than twice as much energy as it absorbs from the Sun, it seems still to be cooling down from the early days of its formation, billions of years ago. Additional heat, possibly from the contraction of light gases in Saturn's interior, was also found by Pioneer 11 at the cloud tops, where "heat" may be a deceptive term by Earth standards—the average temperature is still a frigid -179°C (-290°F).

We know little about the dynamics of the Saturnian atmosphere, and here is where Voyager's close-range TV imaging will reveal more than was possible from centuries of peering through Earth telescopes. Seemingly a bland, yellowish disk in the best existing photographs, Saturn appears from Earth to lack the large swirling storms found on Jupiter. But Voyager 1 has already returned images of the planet that lead to speculation that we may see a more colorful, marked face than has been expected. These mysteries plus questions about the rings and Saturn's known and suspected moons may be cleared up as the Voyagers near their goal.

The Saturn Encounter Begins

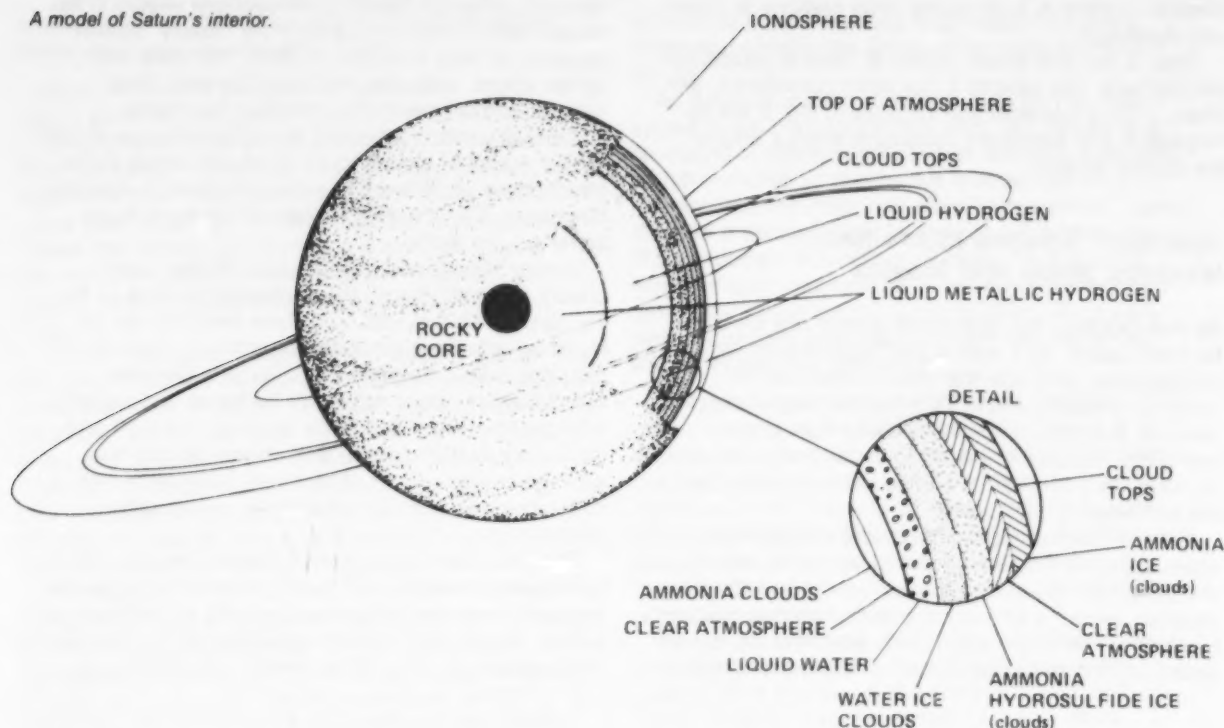
On August 22, 1980, with Voyager 1 still 82 days and a long way away from Saturn, ground commands will load its computers with a batch of new instructions to carry it through the early autumn months, taking almost 4,000 pictures of a gradually enlarging Saturn disk, making extensive long range measurements in radio, infrared and ultraviolet wavelengths, and running continuing scans for charged particles and fields.

The two telemetry (television) imaging cameras—one wide-angle lens and one narrow-angle—are perhaps the truest explorers of this mission, since

Earth and Saturn compared.

	Earth	Saturn
Relative Mass	1	95.2
Diameter at Equator	12,756 km 7,926 miles	120,000 km 74,600 miles
Density (Water = 1)	5.5	0.7
Orbits the Sun in . . .	1 year	29.46 years
Relative distance from Sun (average)	1	9.5
Length of Day	24 hours	10 hours, 14 minutes

A model of Saturn's interior.



they will see the outer planets and their moons from untried vantage points and show us fresh horizons where once we saw only spots of light.

Unlike TV programs on Earth, the telemetry pictures from Saturn will not be broadcast as a continuous transmission, but as thousands of radioed "bits", assembled on Earth into individual images. These images, when taken with different color filters, can then be mixed by ground computers into a color composite photograph. When Voyager nears Saturn another type of composite is needed—mosaics of several narrow-angle frames to form whole images of objects now too large to fit in one shot. These frames overlap slightly to ensure total coverage, and can be assembled later with the aid of a single wide-angle frame that captures everything in its field of view but lacks the quality resolution (ability to see fine details) of the larger lens.

On September 11, one of the approach highlights begins—a "movie" pieced together from a series of photos, one taken every few minutes for ten of Saturn's 10-hour days. The result will be a filmed chronicle of how the planet's atmosphere and rings change over a fairly short time. This is a good opportunity to search for unusual weather systems on Saturn's face, comparable to the huge storms on Jupiter which show up as oval spots even in Earth telescopes. Since few surface markings have been identified on Saturn, these pictures may reveal new

The "C" ring begins at a distance of 13,200 km (8200 mi.) from Saturn's clouds.

Ring or Division	Width
C	10,500 miles
"French" Division	1,125 miles
B	16,125 miles
Cassini Division	2,625 miles
A	9,000 miles

features worthy of a closer look later in the mission.

Another type of movie—with a "zoom" effect—will be constructed throughout the early autumn from pictures taken repeatedly at the same fixed points in the planet's rotation, so that the disk will seem to grow larger, but not to turn. Voyager will photograph five color images each Saturn day to cover various parts of the surface, so that at the end of two months, five separate zoom movies will result, each revealing long-developing changes in the planet's appearance. Now, for the first time ever, Saturn is beginning to show its personality to Earth men.

A very special object of interest, the satellite Titan, also comes under Voyager's daily scrutiny beginning in October, when it appears only pea-sized in a narrow-angle frame. This largest moon in the Solar System is the closest approach target of the entire Voyager mission, at a flyby distance of only 7000 kilometers (4,350 miles—closer even than Voyager

Mission Control is to its signal relay stations in Spain and Australia).

Titan is the only moon known to have a substantial atmosphere, one reason it has been considered, with Mars, to be a possible site for organic life. It will be Voyager's first significant milestone when it enters the Saturn system.

Approach Science Intensifies: Mosaics, Maps and Movies

By mid-October, the spacecraft is only one-third as far from Saturn as it was at the beginning of daily photography, and now the planet's disk can no longer fit (reliably) in the TV's narrow-angle field of view. At this point, one month away from close approach, mosaics are used to cover the planet and its rings. As many as 15 frames will be needed by the first week in November.

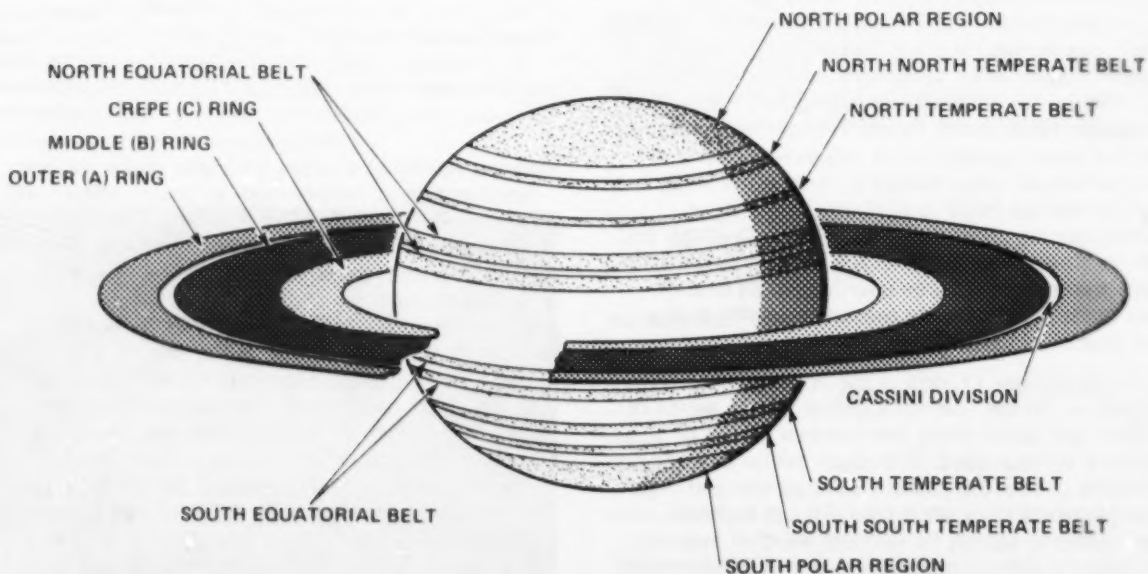
Another rotation movie, beginning October 24, again captures the turning planet to provide an excellent high-resolution look at two days of Saturn weather. Saturn's atmosphere is expected to resemble Jupiter's in many ways. Like Jupiter's, the cloud decks are thought to be layers of water and ammo-

nia ices, although Saturn's atmosphere seems to be thicker and to hug the planet more closely. Saturn appears to have a system of dark, thin belts and lighter zones, probably regions of varying cloud heights and temperatures, banding the visible surface at various latitudes. At Jupiter Voyager found similar zones of clouds to be driven by winds in the atmosphere at different speeds and often in opposite directions. It is unsure that they will behave in the same way at Saturn.

During the approach Voyager's infrared "eye" covers Saturn's disk in the same field of view at the TV camera so that visible surface features can be matched with their temperature profiles. Infrared readings help determine cloud heights (Pioneer found Saturn's polar clouds to be lower and warmer than those at the equator, in contrast to Earth) and can locate holes in the clouds where we see into warmed regions. They also reveal patterns of heat-flow (convection) in the constantly mixing atmosphere.

The ultraviolet spectrometer contributes still more to an understanding of Saturn's chemistry by assessing such important values as the ratio of hydrogen to helium. If Saturn's chemistry is understood, then we can understand more of its history and perhaps its

The geography of Saturn and its three main rings, as seen from Earth. Pioneer 11 discovered two more outer rings in 1979—"F" and "G".



future, which can be compared with what we know about other planets, including Earth.

Now, in the first few days of November, Saturn is truly a giant in Voyager's "eyes". The last mosaic photographs to fit all of the planet and its rings in view will be taken about a week before closest approach. After that, only small parts of the enormous disk or sections of the rings can be targeted. These last whole-Saturn photos should be among the most spectacular views Voyager returns. They should reveal a good deal of structure within the rings.

Not only beautiful natural phenomena, the rings are also influential components of the Saturn system, since they cast shadows (which may affect planetary weather), sweep out large areas in trapped radiation belts, and warp magnetic and gravitational fields. They are composed of countless low density particles (probably water and ammonia ice chunks) orbiting individually around the equator at progressive distances from the cloud tops.

In theory, the rings resulted either from the shattering of a moon or passing body which ventured too close to Saturn's great tidal forces, or from the incomplete formation of primordial planetary material. Unable either to coalesce into a moon or to drift away from each other, the ring particles are held in orbit by the gravitational pull of Saturn and its moon Mimas.

Astronomers historically have seen three separate rings—"C", "B", and "A"—of different brightness and apparent particle density, but Pioneer raised this number to five with its discovery of a new, narrow "F" ring outside of the "A". Another discovery, the "Pioneer" Division, separates these two rings by a distance of 3600 km (2250 mi.).

Pioneer also discovered a distant, sparse "G" ring way out between the orbits of Saturn's two largest moons, Rhea and Titan, but it did not confirm the existence of a proposed inner "D" ring, or the "E" ring sometimes claimed to lie outside of the three main bands visible from Earth. Voyager will search

for both of these "mystery rings" when it passes under and around the plane of the rings on November 12.

As Voyager makes its sweep through the Saturn system it will photograph the rings, the planet, and its moons in differing amounts of sunlight, from head-on full illumination to crescent and dark phases. It will also see the rings and disks from various angles, at close distances. This "phase angle" photography is an important scientific tool, since the quality of reflected light bouncing off of an atmosphere tells a great deal about the cloud composition. Ring particles and moons also disclose their natures by the way in which they reflect light.

In this busy last week before close approach, Titan grows steadily in the field of view, and imaging is stepped up. One object of interest is the hydrogen cloud seen by Pioneer 11 around this moon—evidence of the breakup of Titan's methane (CH₄) atmosphere into hydrogen and carbon, two elements essential to life as we know it. Voyager looks for further signs of escaping hydrogen by watching the ultraviolet spectrum closely.

For many days now, Saturn's moons have been crossing and recrossing the planet's face in the camera field of view, in the endless transit of their orbits. Now, in early November, a few of them appear large enough to permit surveying their surfaces at different longitudes to reveal geological features and color variations, and to search for evidence of atmospheres. Voyager begins to map these brand new worlds.

Just before the spacecraft approaches Titan to begin its 37-hour near encounter with the Saturnian realm, it performs one last whole-Saturn survey. The infrared "eye" patiently scans the entire planetary disk, showing its regional temperature differences. This is supplemented by infrared closeups of the equator and poles and by studies of the optically thinner atmosphere at the planet's edge.

Fields and particles detectors also perform a survey just before Saturn encounter, but with an entirely different purpose. On or about November 11, one day from Saturn, Voyager is expected to confront a bow shock—the violent meeting of the Sun's torrential solar wind with Saturn's magnetic field. This field was only recently confirmed by Pioneer 11. It has about 1,000 times the strength of Earth's field, but only 1/20 the strength of Jupiter's.

Saturn's field was also found to be more uniform than those of the other two known magnetic planets—its axis is almost perfectly in line with its magnetic pole. A powerful force, Saturn's magnetism has created trapped radiation belts where charged particles align themselves along the curved lines of the field, in a fashion similar to the Van Allen belts around Earth.

The known moons of Saturn.

Moon	Avg. Distance From Saturn (thousands of miles)	Diameter (miles)
1979 S1	57	125 (estimated)
Janus	68	125 (estimated)
Mimas	76	590
Enceladus	110	375
Tethys	140	650
Dione	203	625
Rhea	290	1,000
Titan	721	3,625
Hyperion	883	141 (estimated)
Iapetus	2,172	906
Phoebe	8,035	150 (estimated)

There is a slot in this magnetic field where several of the moons sweep out clear paths in the radiation belt particles as they orbit. A similar sweeping out occurs under the rings, the most radiation-free areas known in the Solar System.

Because of the ebb and flow of the solar wind, Pioneer crossed a bow shock several times on its historic first visit to Saturn, and Voyager is expected to possibly do the same thing at similar distances (about 12 Saturn diameters). On close approach, the ultraviolet instrument will also look for signs of two more fascinating magnetic effects—a torus (a doughnut-shaped cloud of charged particles surrounding a moon's orbit) at any of Saturn's closer satellites and the existence of auroral phenomena caused by impact of charged particles within the planet's atmosphere.

Encounter With Titan

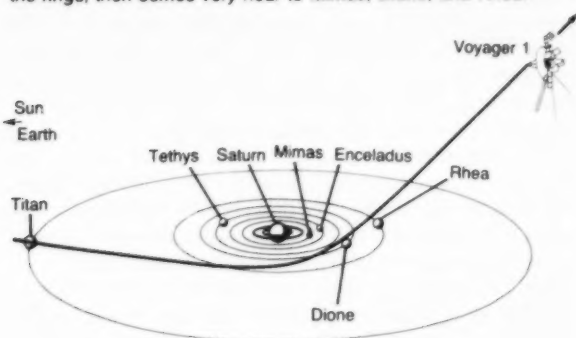
Late on the night of November 11, mission controllers will wait anxiously for their first news of an event already an hour and a half in the past—a close flyby of the eastern hemisphere of Titan. Voyager 1's encounter trajectory (past Titan, under Saturn's south pole, then an ascent outside the rings) was chosen especially to reach Titan before closest approach to Saturn so that the risk of missing out on study of this unique sub-planet would be lessened.

The recent discovery of colder temperatures at Titan than had been expected—its cloud tops are 324° below zero(F)—combined with doubts as to whether or not there is a significant surface pressure, have seemed to lessen the chances of finding life there. But the possibility remains—especially if Titan's surface is heated by ultraviolet radiation in the upper atmosphere, or if there is a "greenhouse" effect allowing heat to be trapped under a cloud cover.

An artist's conception of what the surface of Titan might look like to someone on its surface, with lakes of methane evaporating into the atmosphere. (Artist: Ron Miller)



Voyager 1 flies by Titan (left), passes under Saturn and outside of the rings, then comes very near to Mimas, Dione, and Rhea.



Titan's density indicates that it probably has an icy interior, but its atmospheric makeup is not established. As Voyager rounds the moon near its equator, it attempts to remedy this situation. Passing behind Titan, the spacecraft will become hidden, or "occulted" from Earth's view and will go into the moon's sun shadow. This brief (12 minute) occultation period is an extremely productive time for atmosphere study, when thousands of bits of data will be tape-recorded for replay once Voyager is again in contact with Earth.

In the first occultation experiment, just as Voyager is about to be eclipsed by Titan's solid surface, a radio beam is sent through a cross-section of the atmosphere extending out from the moon's edge. By

seeing how this beam's path and strength are affected, the atmosphere's mass and its structure are determined. The experiment is repeated just as Voyager reappears from behind the moon.

Similarly, the ultraviolet device takes advantage of Voyager's passage through Titan's shadow to analyze sunlight filtering through the atmosphere just before occultation. This, combined with infrared studies and a special methane-detecting filter in the TV cameras, will provide the best data yet on the composition of Titan's "air".

Most exciting of all, though, will be the first-time-ever looks at Titan returned by the TV cameras. Other than a generally reddish color, we know little about what to expect to see in these photos. Titan may have a transparent atmosphere or it may have a thick cloud cover like Venus. If there are clouds, it is hoped that there will be enough breaks to permit some viewing of the surface, where features only a few hundred yards across would be seen. Either way, the mosaic photos of Titan should be every bit as spectacular as those of Jupiter's moons.

Descent to Saturn's South Pole

On leaving Titan, Voyager makes backward-glancing searches for lightning bolts on the moon's dark side. Now begins a descent to Saturn's south polar region, where, the next afternoon, it will pass the cloud tops at a distance of about one Saturn diameter.



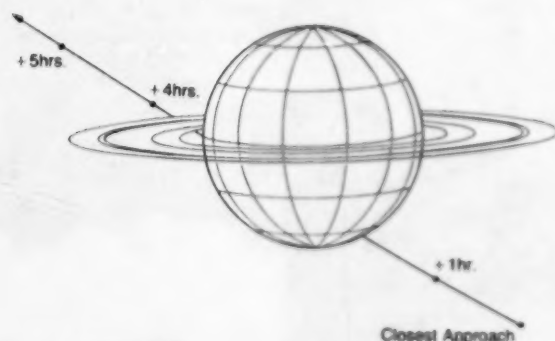
The ring occultation experiment. Voyager 1 analyzes sunlight filtering through the rings and sends a radio beam back to Earth (in the direction of the Sun) to see how it is blocked or scattered by particles.

The speed of the gravity-boosted spacecraft is tremendous during these hours before and after Saturn approach, when Voyager will be traveling 31 kilometers (19 miles) each second. At this speed, some 40 times faster than an M1 rifle bullet, it would take barely a minute to travel the distance from New York to Texas. Satellites will loom ever larger in the TV camera's shifting field of view, then be passed almost as soon as they are encountered.

Nearly at the same time it begins its descent, Voyager also crosses below the plane of Saturn's rings. This produces a curious effect—until the spacecraft crosses above the ring plane again, its cameras will return photos that appear reversed in sunlit Earth views. Areas with little or no particle density will let sunlight through and appear very bright, while the rings themselves will block the light and appear darker. Ring photos will seem like "negatives".

Nearer and nearer to Saturn, Voyager scans the surface in various wavelengths and takes very close pictures of the south polar region at resolutions of only a few kilometers. At 3:46 p.m. (Pacific time) on November 12 the Voyager 1 spacecraft, a tiny speck above Saturn's clouds, marks another milestone in history by "reaching" this distant planet at 40 degrees south latitude. But this news won't reach Earth for 90 minutes, shortly before the spacecraft passes behind the planet.

As seen from Earth, Voyager 1 goes behind Saturn and its rings shortly after closest approach to the planet. It tests the clouds and the ring structure just as it becomes hidden, or "occulted".



Occultation studies of Saturn's atmosphere proceed much as they did at Titan, although the time of Earth eclipse—87 minutes—is much longer. When Voyager again peeks out from behind the disk, there is an especially good occultation opportunity in a narrow gap between the planet and rings, when instruments will study the upper clouds and then search for the inner "D" ring.

As it crosses behind the planet, the spacecraft also begins its ascent to the plane of Saturn's

equator and its rings. Four and a half hours after the closest Saturn approach, it crosses this plane again, well outside of the main rings themselves, at a distance of seven Saturn radii. This is a fine chance to study the rings at a close range, first from below, then from above, using mosaics, phase angle views, infrared scans and occultation studies.

The first object of concern is the size of the individual ring particles. While most are thought to be the size of snowballs, it is possible that there are large kilometer-sized chunks which could even show up as bright points of light in sunlit views at close range. Voyager can also help determine if the rings are just one, or many layers of particles in thickness.

The next matter of interest is the composition of the particles, revealed in part by infrared study of temperatures in the diffuse "C" ring and by the scattering of light from their presumably icy surfaces at different angles. Voyager can also check for cross-plane motion within a ring or for bunching of particles near the edges, in a further search for clues about how they were formed.

Occultation studies using the Earth, Sun and stars are crucial to the ring investigation. During the 20-minute transit behind the rings, radio beams sent through them will be either blocked or scattered by the particles, revealing their size and distribution. Of special interest is a feature known as the Encke Gap in the "A" ring, and the Cassini Division—an apparently clear area between the "B" and "A" rings—where Pioneer nevertheless found substantial particle material. Cassini's Division, wider than the Earth's Moon, is caused by the gravitational effects of the moon Mimas.

Finally, Voyager will have a good chance to look for any disputed rings or small satellites between the planet and the edge of the "F" ring, where Pioneer found a tiny moon in 1979. The ultraviolet device can also search for magnetic interactions between the rings and the planet.

In the meantime, several of Saturn's moons will be inspected quite closely. After a distant, pre-Saturn flyby of Tethys and a medium-range encounter with asteroid-sized Enceladus, Voyager makes close-up mosaic maps of Mimas, Dione, and Rhea during a five-hour period starting just before the planetary occultation.

All of these moons are expected to consist largely of frozen water, but almost nothing else is known. We will be seeing their faces for the first time. Surveys of each satellite's surface at different phases and longitudes may reveal the smooth iciness of Jupiter's moon Europa, or they may show craters, plateaus, and mountains. By measuring the gravitational effects of the satellites on Voyager's speed, a good estimate of their masses and densities can also be deduced.

Closest approach distances for the Voyager mission.

Target	Voyager 1		Voyager 2 (Uranus trajectory)	
	Km.	Miles	Km.	Miles
Saturn	124,000	77,190		
Titan	7,000	4,350		
Mimas	108,000	67,500		
Dione	162,000	101,250		
Rhea	73,000	45,625		
Saturn			101,000	63,000
Tethys			93,000	58,125
Hyperion			471,000	294,375
Enceladus			87,000	54,375
Iapetus			918,000	573,750
Phoebe			1.4 million	893,750

Especially good pictures should return from Rhea, Saturn's second largest moon and the next closest approach target (after Titan) for Voyager 1. Hyperion, an apparently non-icy moon, will also be photographed, but at a distance that will not allow for great detail.

Voyager Looks Back at Saturn

By the morning of November 13, Voyager will already be a million kilometers past Saturn, and will again be returning "positive" sunlit images of the rings as it looks down on the planet. Saturn itself will be mostly dark now that the Sun is shining on the other side from Voyager's vantage point, and will only present a small crescent that is fully illuminated.

Almost half of Voyager 1's total of 14,000 Saturn pictures will be taken during the next month of post-encounter study, and with good reason. This view of the ringed planet—from the far side of its orbit—has never been photographed before, and no one knows just how the rings (which present many faces even to Earth telescopes) will appear. Long-exposure shuttering of the planet's dark side will serve to detect lightning bolts similar to the ones Voyager found in Jupiter's higher clouds.

During this month many of the approach studies are duplicated, but in the case of the post-encounter "zoom" movies, their sequence is reversed—instead of growing larger, Saturn's disk will appear to shrink. Rotation movies of the partly illuminated planet will again be made, and the infrared instrument will build another map of Saturn's atmosphere, similar to the inbound one.

One continuing task is the search for new satellites both near the rings and beyond them. Several tiny moons have been reported from Earth observations in the last few years, and Pioneer detected a number of unexplained wakes in the sea of charged particles

around Saturn in addition to the one moon it actually "saw". It is possible that Voyager's TV cameras may add one or two new satellites to the eleven now known.

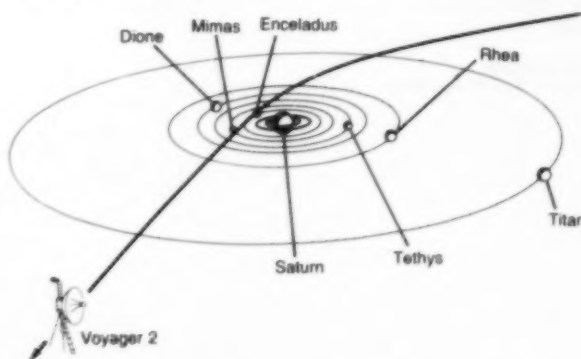
As the spacecraft leaves Saturn farther behind, it makes continued measurements of the magnetic field expected to trail at a considerable distance from the planet. Voyager 1 has a trajectory which takes it away from Saturn at an upward angle, and eventually out of the Solar System. The spacecraft ends its Saturn observations on December 15, 1980, but will continue to transmit data periodically as it heads on an infinite journey through space.

And on this journey, Voyager has one last purpose. A playable record of Earth sounds, music, and pictures is carried aboard in a gold disk attached to its outer surface. This "Earth message" to possible intelligent beings in the far reaches of the universe is both visionary and intriguing in its purpose—to inform anyone who might be listening of the state of civilization on Earth. Voyager carries recorded samples of our planet's culture with it.

A Second Visit to Saturn

The second phase of the Voyager Saturn mission begins June 5, 1981, when Voyager 2 starts its approach observations. Closest flyby will be on August 25, at a distance of 101,000 km (63,000 mi.). The lag time between the two spacecraft has now widened from four months at Jupiter to more than nine months so that Voyager 2 reaches Saturn at a time favorable for a boost on to Uranus.

Voyager 2 goes around Saturn's Northern hemisphere, closer to the rings than Voyager 1.



Science investigations by Voyager 2 at Saturn almost exactly parallel those of the first spacecraft. Two trajectories are possible—one which revisits Titan at close range in the event that Voyager 1 was for some reason unable to do so, and the other, more likely path that sends the spacecraft on to Uranus. If Voyager 2's computers are commanded to

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take it on to the next planet, it will pass up a close look at Titan and will not have the opportunity for ring occultation experiments. But it will pass slightly closer to Saturn and the rings, on a trajectory which take it around the planet rather than under it.

This different trajectory also allows for another good look at Mimas and closer flybys of Tethys and Enceladus, in order to complement the Voyager 1 mission. Two more satellites will also be viewed from a distance—Phoebe, which orbits Saturn in the opposite direction from all its other moons, and Iapetus, interesting because it is five times brighter on one side than on the other, possibly due to an uneven distribution of frost on its surface.

Voyager 2 should add to the already impressive exploration of its twin, and perhaps will inspect further any surprise discoveries of the first mission. If it is successful at Saturn, Voyager 2 will end operations related to that planet September 27, 1981, then travel another five years to even more distant Uranus (1986) and possibly Neptune in 1989, in a continuation of its historic tour of outer space, the most ambitious of man's explorations to date.

Suggested Reading

Voyager mission and experiments:

Space Science Reviews, Volume 21, Numbers 2 and 3: November and December, 1977.

Voyager at Jupiter:

National Geographic, Vol. 157, No. 1, January, 1980, pp. 2-29.

Pioneer 11 at Saturn:

Pioneer Saturn Encounter, NASA Ames Center, September 1979. *Science*, Vol. 207, No. 4429—January 25, 1980.

The Planet Saturn:

The Cambridge Encyclopedia of Astronomy, Crown Publishers, 1977, pp. 219-223.

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U.S. GOVERNMENT PRINTING OFFICE: 1980 O-330-057